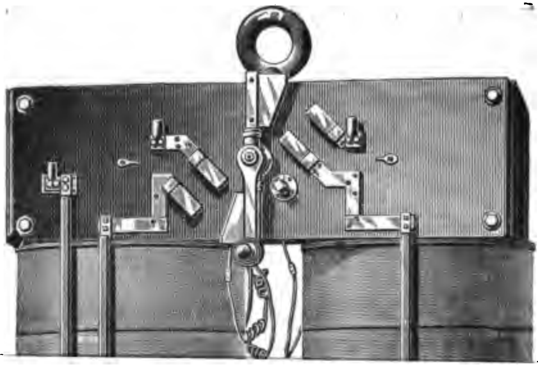
AMO

NE.



HOW TO MANAGE

THE DYNAMO

A HANDBOOK

FOR

SHIP ENGINEERS, ELECTRIC LIGHT ENGINEERS,
AND ELECTRO-PLATERS

BY

S. R. BOTTONE

AUTHOR OF "THE DYNAMO, HOW MADE"; "ELECTRO MOTORS"; "ELECTRIC BELLS"; "ELECTRICAL INSTRUMENTS"; "A GUIDE TO ELECTRIC LIGHTING"; ETC., ETC.

New York
MACMILLAN AND CO.
AND LONDON
1893

Ward fund

ROBERT DRUMMOND, ELECTROTYPER AND PRINTER, NEW YORK.

PREFACE.

THE following pages are intended specially for the use of those who, being thoroughly good engineers and capable of managing ship or land engines, find themselves suddenly called upon to undertake the management of the dynamo of an electric light or electro-plating installation. The instructions given apply more particularly to the dynamo, its management, its defects, and their remedies. No attempt will be made at explaining the theoretical or constructional details; *these* will be found in other works by the author. In order to facilitate the comprehension of such technical terms as are absolutely requisite in a work of this kind, a table of definitions is subjoined, and will be found at the end of the book. To this table the reader is referred for explanation of special terms.

S. BOTTONE.

HOW TO MANAGE THE DYNAMO.

§ **A.** A dynamo is a machine, by the aid of which energy, in the shape of motion, is transformed into energy in the form of electricity. Although the forms given to dynamos are many, yet the essential portions are in all very much alike. They consist in (*a*) a fixed mass of iron wound with many turns of insulated copper wire, which, when the machine is working, becomes powerfully magnetic, and therefore called the field magnets; (*b*) a rotating mass of iron also wound with insulated copper wire, which generates a current when rotated between the poles of the aforesaid field magnets, and which is called an armature; (*c*) a ring of two or more sections of brass, copper, or phosphor bronze, each one of which is separated from its neighbour by some insulating substance, which ring, being in connection with the ends of the wires of the armature,

collects the electricity generated and transmits it to (*d*) the brushes, that consist in strips of copper supported on insulated holders, which strips press upon the sections of the ring of the collector. In connection with these essential portions we have the *shaft* or *spindle* which carries the revolving armature; the standards and bearings which support the shaft and the pulley, by means of which motion can be imparted to the armature. Fig. 1 illustrates a typical

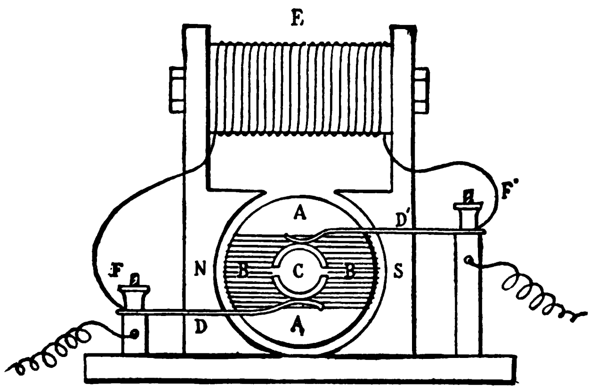


FIG. 1.

form of dynamo in which E is the fixed mass of iron or field magnets wound with insulated wire, of which the pole pieces (also in iron) N and S are but prolongations; AA is the armature or revolving

iron portion, coiled with the wire BB, the ends of which connect to the collector or commutator C; D and D′ are the brushes which convey the current

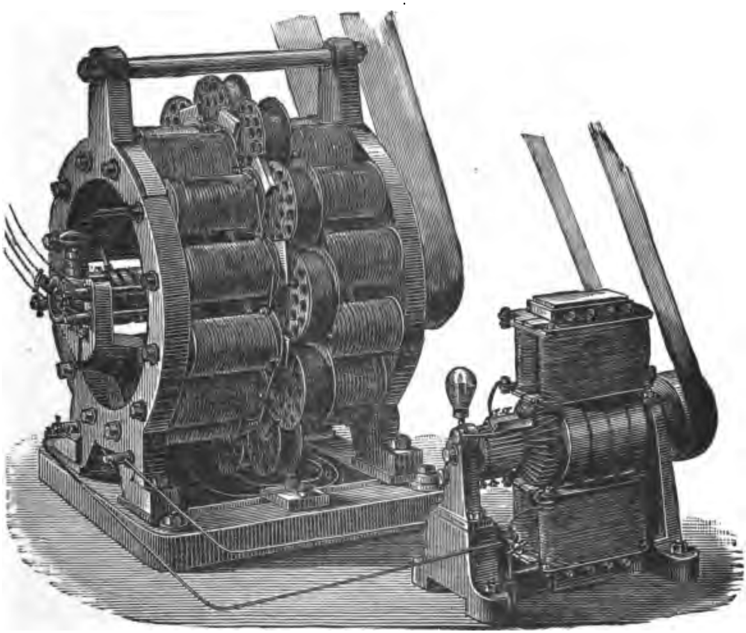


FIG. 2.

from the collector to the terminals F and F′. Dynamos may be divided into four classes, namely: 1st. Those in which the field magnets are magnetised by a current supplied from an external source. These

are known as *separately-excited dynamos*, and are generally used in those cases in which an alternating current is required. Fig. 2 illustrates one of these, in which the small figure to the right represents the exciting dynamo which magnetises the many field magnets of the large generator or dynamo to the left. 2nd. Those in which the whole of the current generated in the armature is caused to circulate

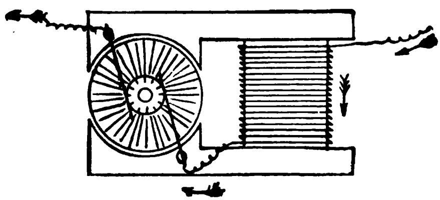


FIG. 3.

round the coils of the field magnets on its passage to the outer circuit, and thus to magnetise them. These are called *series* machines. This arrangement is shown at Fig. 3. 3rd. Those in which a portion of the current set up by the armature is deviated or *shunted off* in its course to the outer circuit and caused to flow round the field magnets to magnetise them, as shown at Figs. 4 and 1, and hence called shunt machines. 4th. Machines in which the

field magnets are wound with two distinct sets of wires, one set being connected in series, and the other in shunt; these are called compound-wound

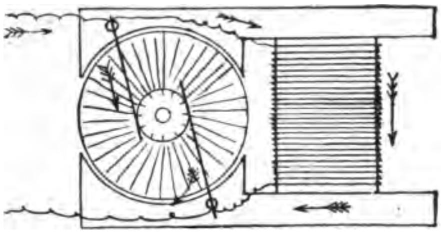


FIG. 4.

dynamos, and the mode of winding is illustrated at Fig. 5.

§ **B.** The principle on which all these machines

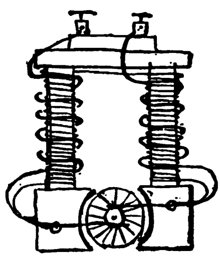


FIG. 5.

(with the exception of the first class) act is the same, namely, the iron of the field magnets acquires and retains, during the process of manufacture, a small

amount of magnetism; when the armature is rotated before the poles of these weak magnets, a weak current of electricity is set up in its coils, and the whole or a portion of this current, traversing the coils which surround the field magnets, increases their magnetism, which in turn sets up a larger current, and so on; the field magnets and the armature react on one another until after a few revolutions of the armature the field magnets become duly magnetised and the armature gives its full output in current. In machines of the first class the current supplied by the small exciting dynamos magnetises the field magnets of the larger machine, and this magnetism is converted directly into electricity on the rotation of the armature between the pole pieces of the large machine.

§ C. In machines of the first class, as the magnetisation of the field magnets is totally independent of anything which may be put in the way of the current supplied by the generating dynamo, so the output of the machine is independent of any variation which may take place in the outer circuit. (By outer circuit is meant that portion of the circuit in which useful work is being performed, such as lighting, plaiting,

driving motors, etc.) The electro-motive force, and consequently the current in these machines, can be increased by increasing the speed of rotation. Care, however, must be taken not to increase the current beyond the carrying power of the wire with which the armature is wound.

§ D. In machines of the second class, or "series" machines, since the whole of the current which passes round the field magnet coils to magnetise them is obliged also to traverse the outer circuit, it follows that if any great resistance be placed in the outer circuit, but little current will flow round these coils, and consequently the field magnets will be slightly magneised, and therefore only a small current will be set up, and the greater the resistance placed in the outer circuit the less the magnetism, and consequently the less the current. Hence, with series-wound machines, the resistance in the outer circuit must be kept within certain well-defined limits; otherwise, if the resistance be too low, so large a current will be generated as heat up the coils both of field magnets and armature, and to burn the insulating covering with which these coils are wrapped; or if the resistance be too great, the

field magnets will not be sufficiently magnetised, and the machine will fail to give the desired amount of current.

§ E. In machines of the third class, or "shunt" dynamos, as they are usually termed, the field magnets are wound with many coils of fine wire, which consequently present considerable resistance to the passage of the current. The amount, and consequently the resistance, of the wire coiled round the field magnets of a shunt machine should be about four hundred times the resistance of its armature. Now, since the resistance of the outer circuit should not exceed twenty times that of the armature, it follows that when a fair load is put on the machine, as both the field magnet wires and the outer circuit are directly connected to the brushes, the current set up in the armature, finding two paths open to it, namely, round the field magnet wires, and round the outer circuit, divides itself along these two paths in quantities inversely proportionate to their resistances; that is to say, twenty parts will pass round the outer circuit and only one part round the field magnet wires. But since the magnetising power of a given current can be in-

creased to any desired extent by increasing the number of turns which the wire carrying the current makes round the iron, it follows that the field magnets will be sufficiently magnetised when one-twentieth of the total current is passing round these field magnet coils, provided these make a sufficient number of turns. The shunt dynamo possesses a considerable advantage over the series-wound dynamos in two points. Firstly, a very considerable amount of variation of resistance may be introduced in the outer circuit without stopping the work of the dynamo. For instance, suppose a large resistance were inserted in the outer circuit, this would compel a larger quantity of the current to pass round the field magnet coils, and in doing this cause the field magnets to become more intensely magnetised, and therefore in their turn to set up a higher electro-motive force to overcome the excessive resistance. On the other hand, if a low resistance be inserted in circuit, more current traverses the outer circuit, as its resistance is less than the field magnet coils, so that the field magnets become less magnetised; the consequence being that less electro-motive force and less current is produced. Secondly, there is

less risk of injuring the dynamo itself by altering the conditions of the outer circuit. In the series dynamos as we have seen, if a very low resistance be placed in the outer circuit, so large a current is produced and carried through the coils surrounding the field magnets and armature that the insulation is nearly sure to be burnt up; while in the case of the shunt dynamo, the lower the resistance in the outer circuit the less current passes round the field magnet coils; and even if the outer resistance be greatly increased the very great resistance of the field magnet coils themselves prevents any very large amount of current from passing through them, so that the shunt dynamo is much less subject to injury from sudden variations in the outer circuit than the series dynamo. Still, it is not well to allow a shunt dynamo to run for any considerable length of time with nothing, or a very high resistance, in the outer circuit, since, under these circumstances, the field magnet coils would slowly but surely heat up.

§ **F.** The compound-wound dynamo is, by virtue of the two independent sets of field magnet wires, eminently adapted for all cases in which the varia-

tions in the resistance of the outer circuit may be very great. The armature is wound with wire having approximately twenty times the resistance of the usual outer circuit. The series or coarse coils on the field magnets have a resistance of about two-thirds that of the armature, while the shunt coils have a resistance nearly twenty times as great. The series coils start from one brush, go round both field magnets, and one end terminates in one of the terminals. The shunt or fine wire coils are both connected to the brushes. The effect of this arrangement is that if a very low resistance be placed in the outer circuit, the whole of the current can and does traverse the series coils; if, on the contrary, a very high resistance be placed in the outer circuit, a considerable portion of the current is forced through the fine shunt coils, sufficient in quantity to magnetise the magnets and set up an electro-motive force capable of overcoming the increased resistance. Owing to this, a well-constructed compound-wound dynamo is capable of feeding its full load of lamps, or of having any number thrown out of circuit without injury either to the lamps or to itself.

§ **G.** The portions on which the rotating armature is suspended, technically called the bearings, should, in a well-constructed dynamo, be long, and sufficiently strong to resist all vibration. The lubrication should be carefully attended to, and it should be seen that the spindle which carries the armature should have a little end play between the bearings, otherwise, if it run absolutely in one position, the commutator (the ring of copper segments which collect and distribute the current from the armature is so called) will become deeply grooved and scored.

§ **H.** The brushes, which consist usually of copper, either in the form of wire, sheet or gauze, should press lightly, evenly, and yet firmly on the rotating commutator. On the condition of the brushes a great deal of the efficiency of the machine depends.

§ **I.** In all good modern machines the brushes are retained in position by an oblong piece of wood or metal, riding over the bearing near the commutator end of the dynamo. This brush-carrier is technically known as a "rocker," from its capacity of being *rocked* from one side to the other of the standard or bearing, as occasion may require.

CHAPTER I.

ON INSTALLING A DYNAMO.

§ 1. When a dynamo arrives from the maker's, the first operation will be to place it in position. Here judgment is required: firstly, with regard to the choice of a perfectly sound and vibrationless bed; and secondly, with regard to its situation with reference to the engine, since it is well that the slack of the belt which conveys the power from the engine to the dynamo should be uppermost, as by this means the belt embraces more of the pulley and consequently there is less slip. The direction in which the dynamo should be driven in order to produce currents is generally indicated by the position in which the brushes lie upon the commutator, and care must be taken not to drive against the brushes, lest injury be done to the commutator. Most makers send out their dynamos so coupled up that they run clockwise when viewed from the pulley end. All large dyna-

mos, absorbing from twenty horse-power upwards, should be bedded on a solid brick or stone foundation. If the field magnets have the poles upwards, the frame of the dynamo may be bolted directly to the foundation, even if the foundation consist of iron; but if the dynamo be of a type which has the pole pieces downwards, the avoidance of all masses of iron in the base or anywhere in the vicinity of these pole pieces, is strongly enjoined: because the presence of any masses of iron in their neighbourhood would, by diverting the magnetic field from the armature, create a great loss of power. In view of the advisability of keeping the dynamo out of dust, moisture, or dirt of any kind, it will be well that the foundations should be raised from six inches to a foot above the level of the floor. Many makers send out rails and belt-tightening gear with their dynamos, which can be set on the foundation without necessitating any alteration. The firmness and the rigidity with which a dynamo and its foundation are connected together have a great influence upon the life of the commutator. When the body of the machine, or, worse still, of its setting, vibrates, the

brushes, especially if the rocker and brackets are at all of a flimsy character, partake in an increased degree of this vibration, and by jumping off the commutator, set up little "arcs" or flashes of light which burn, roughen, and eventually ruin the commutator bars.

§ 2. Though the engineer called upon to take charge of an installation may find the motive power already fitted, and consequently not have much voice in the matter, yet it is well for his own sake that he should remember that the steadiness (by which is meant the running without any variation in speed or power) of the motive power is a great factor in the successful working of electric lights. As arc lights are produced between larger masses of carbon than incandescent lights, and as the carbons in the former when once heated to incandescence retain, by reason of their mass, the heat for a longer time, so are arc lamps less sensitive to any small changes in the speed or power of the motor (be it wind, water, steam, or gas) by which the dynamo is driven. In the case of steam engines, water motors, and hot-air engines, this variation is

generally very small; but in gas engines, especially in those in which an explosion takes place only once in every two or three revolutions, the variation in speed is very great, and makes itself painfully evident by the alternate bobbing down and flashing up of the lights. Perhaps nothing is so effectual in overcoming these annoying fluctuations in the speed of a gas engine as the addition of a good heavy balance wheel at the driving extremity of the shaft of the dynamo; but then, in order to avoid all risk of unequal wear of bearings, it is well to have a third and outer standard to take the additional weight of this fly-wheel. In conveying power from the engine, etc., to the dynamo, belts are generally used. These should be, as far as practicable, long; as there is less slip with a long belt than with a short one. It is also advisable that the belt should run either horizontally or at an angle not exceeding forty-five degrees. Belts running vertically are to be avoided. They should be endless, since any *joins* will cause a fluctuation in the light each time they pass over the pulley. Those known as leather-chain belts present some advantages, being somewhat more flexible, and

having a better grip on the pulley than solid leather belts. Driving by means of ropes finds favor with many, especially for large dynamos, in consequence of the advantages this system possesses in providing against stoppage consequent upon the breaking or slipping of belts, since, by employing this system, as many as ten or a dozen ropes may be running at once in separate grooves on the engine and dynamo pulleys. On board ship and for large central station dynamos, *direct driving* is extensively used. In this case the shaft of the engine and the shaft of the dynamo are coupled directly together. Provided the engine perform a sufficient number of revolutions per minute and maintain a regular speed, this system is at once the most economical and the most efficient mode of driving the dynamo. Chain gearing, similar to that used on tricycles, has been used in small dynamos, and is considered by some to possess advantages; this is not, however, in conformity with the author's experience.

§ 3. The dynamo having been set up and the position of the engine with reference to it having been duly determined, the dynamo should be carefully

examined, and any dirt which may have collected either during transit or otherwise carefully removed. If the armature should have been sent separately, then all the iron and brass parts which require to be fitted together should be carefully cleaned, and the armature, especially if a heavy one, most carefully handled with a view to avoiding any accidental injury to the insulated wire upon it. For this purpose it should be grasped by the shaft only, with a hand at each end, or supported on some waste placed on a board as long or longer than the armature, which should be carried by an assistant, the shaft being also supported by other hands. On no account should the armature be supported by its commutator, as this may be thrown out of true or otherwise injured, to the great detriment of its working. The practical engineer will at once understand that when in place the armature must ride free from the pole pieces and not bump or knock at any part. It must also turn easily on its bearings, not showing any tight places, for these will surely heat and give trouble.

§ 4. All moving parts of the dynamo at the place

where they rest upon their bearings should be kept carefully lubricated. In practice a Stauffel lubricator fed with lard, or a similar semi-solid fat, will be found to give satisfaction. Small dynamos can be lubricated with oil, supplied from a needle-feed lubricator. Since it is not advisable that the commutator should be oily, or that any oil or grease should get on the armature wires, many dynamos are furnished with discs on the shaft, one just before the commutator and the other just behind the wires at the driving end, which discs serve to throw off, by centrifugal tendency, any oil which may happen to creep towards the armature. It is not advisable to lubricate the commutator, at least not to any appreciable extent. Any large quantity of grease causes excessive sparking, sops into the insulation between the sections of the commutator, gets burned there under the influence of the sparks, and by being carbonised produces short circuits, which in their turn ruin the insultation of the armature wires themselves. The utmost that is admissible in the way of lubricating the commutator is to place a little drop of oil in the palm of the hand, and having rubbed both hands together so as to spread the oil, to wipe off the

superfluity with a piece of cotton waste, and then hold the hand against the commutator whilst it is being gently rotated. It will be self-evident that the commutator must run beautifully true; for if it do not, uneven spaces, technically known as "flats" are formed by the sparking at the uneven places. Even with the very greatest care irregularities will sometimes form on the commutator. If these are very slight they can be ameliorated by holding a piece of fine emery paper, stretched on a flat piece of wood as wide as the commutator, against the commutator whilst the armature is running; but if they are of any importance it is better to take the armature out and turn it up dead true on a lathe. After running for a short time a well-centred and true commutator becomes skinned over with a bronzy-looking glaze; and when in this condition, if care be taken that the brushes do not become ragged or uneven, may easily be retained in perfect working order.

§ 5. The disposition of the brushes is a matter of considerable importance. They should press, in well-constructed machines, at two points on the circumference of the commutator diametrically opposite to each

other.* The exact position on the circle will depend somewhat on the nature of the machine. In dynamos having ring, drum, or similar armatures, the brushes will lie at points parallel with the spaces between the pole pieces of the magnets, and will be tilted forward a little in the direction of the motion of the dynamo. The amount of tilting forward, or "lead" as it is technically called, will be greatest in the case of series-wound dynamos, less in the shunt-wound ones, and least in those which are compound-wound. The best position of the brushes may be found experimentally by gently rocking the brush-carrier while watching at the same time the commutator and the lights. That position is best which gives at once the most brilliant light with the least sparking at the brushes.

§ 6. The *commutator* should next be carefully ex-

---

* This does not apply to machines of the "four-pole" type, such as the "Victoria brush," etc., in which two or more sections are coupled together, to admit of the use of one pair of brushes instead of two. If we liken the position of the brushes on the commutator to the hands of a clock, then in an ordinary two-pole machine the brushes will be resting on IX and III, or XII and VI, etc., as the case may be; but in the four-pole machines of the Victoria brush type, the brushes must rest on XII and III, or I and IV, II and V, etc.

amined. Sometimes little particles of copper or brass filings get embedded in the insulation that is placed between the commutator plates. These should be carefully removed, because any such particles would bridge over between one plate and the other, producing a short circuit, which might lead to a breakdown in the armature itself.

§ 7. The purchaser of a dynamo will generally have given to him by the maker some notification of the speed at which the dynamo may be driven to produce the best results. In case this information may not be forthcoming the following data will enable the engineer to determine, in a fairly accurate manner, the number of revolutions that the armature should make per minute. Having taken the diameter and length of the armature in feet, he adds these two measurements together and divides the constant 1250 by them. The result will be approximately the number of revolutions which the armature should make per minute. A trial afterwards will determine the exact speed; for instance, let us suppose that the diameter of the armature were 6 inches $= \frac{1}{2}$ foot and its length 1 foot. Dividing 1250 by $1\frac{1}{2}$ we get: $1250 \div 1{\cdot}5 = 833{\cdot}3$, or

nearly 834 revolutions per minute. The above calculation gives the theoretical speed for a perfect machine; in practice the speed required will be somewhat higher; but the larger the machine the nearer will the above calculations approach to the truth.

CHAPTER II.

Defects Inherent to Dynamos.

§ 8. *The dynamo will not start working.* This defect may depend on several circumstances. If the dynamo is series-wound and insulation good at all points, either the resistance in the outer circuit (lamps, etc.) is too high, or else the field magnets do not retain sufficient residual magnetism. In the first case it will be advisable either to use lamps of lower resistance, or else to use a larger number connected in parallel, which lowers the total resistance. In the second case, while the dynamo is running at its normal speed, the two terminals may be connected for a second by means of a piece of very stout copper wire. To do this the operator will insert one end of the wire in the hole of one of the terminals, and with the loose end of the wire just touch the other terminal. In all probability the dynamo will give a heavy flash when the terminal is touched; and if the wire were left in contact, either the armature wires would be fused by the heavy current produced, or else the belt thrown off the pulley

owing to the excessive power needed to drive the dynamo while producing this large current. Hence, care must be taken never to leave a series dynamo short circuited for any appreciable length of time. Another cause to which this defect may be owing is that of *reversal.* If a series-wound dynamo has been used to charge accumulators, to do plating work, or has been run as a motor, its proper polarity may have become reversed, so that it will not generate current at all unless driven in the opposite direction, namely, against the brushes. Now, as it is not possible to run a dynamo as usually constructed against its brushes without serious injury either to brushes or commutator, the quickest way to remedy this defect is to uncouple the field magnet wires, which are connected respectively to one brush and one terminal, and reverse them; that is to say, to connect the one which previously went to the brush, to the terminal; and the one which was formerly coupled to the terminal, to the brush.

§ 9. In the case of shunt-wound dynamos, the causes of failure to generate current (always presupposing that the insulation is good at all parts), may depend upon either too low a resistance in circuit, or

insufficient residual magnetism in the field magnets. As we have seen at Section E, the resistance of the field magnet coils in a shunt-wound dynamo is high as compared to that of the outer circuit; so that if the resistance in the outer circuit be reduced below a certain point, sufficient current will not flow round the field magnet coils to magnetise them, and the machine will not work. The remedy to this state of things is, either to use lamps of higher voltage or to diminish the number of lamps, or if the lamps are of very low voltage, to run them in sets of two or three in series, the sets in series being placed in parallel across the mains. To reinforce the residual magnetism of the fields, all the external circuit must be disconnected from the terminals of the shunt dynamo; the machine must then be run at its normal speed for about a minute (by which means the whole current which the dynamo is capable of supplying is thrown into the field magnet coils, so as to magnetise the field magnets), and then the lamps, etc., suddenly thrown into circuit.

§ 10. But this defect may be due to causes not exactly pertaining to the dynamo itself. The binding screws or terminals may make bad contacts, by

not being clean or not screwing down tightly; or there may be poor contacts along the line; or one of the connecting wires which couple the brush holders to the field magnet wires or to the terminals may have become loose or detached; or, lastly, the brushes themselves may be in the wrong position.

§ 11. But the most fruitful source of the non-working of dynamos, is a want of insulation, or a short circuit somewhere. This short circuit or leakage may occur either (*a*) between the wires on the field magnets and the field magnet cores themselves; or (*b*) between one or more coils themselves; or (*c*) between the wires on the armature and the armature core itself; or (*d*) between the individual coils of the armature. Or, again, (*e*) there may be leakage between the commutator bars; or (*f*) between the brush holders and the rocker; or (*g*), the wires or "leads" or mains touch at some point; so that the current is short-circuited at the point of contact. Even in a lamp holder it may occur that the two hooks have got crossed, and thus produce a short circuit.

§ 12. We will now proceed to show how these dif-

ferent short circuits may be localized and remedied. To detect a leakage between the wires of the field magnets and the field magnet cores, remove the brushes from off the commutator; connect one pole of a battery, giving at least fifty volts to one terminal of the field magnet wires, and connect the other pole to an ordinary linesman's detector or galvanometer, and take a wire from the other binding screw

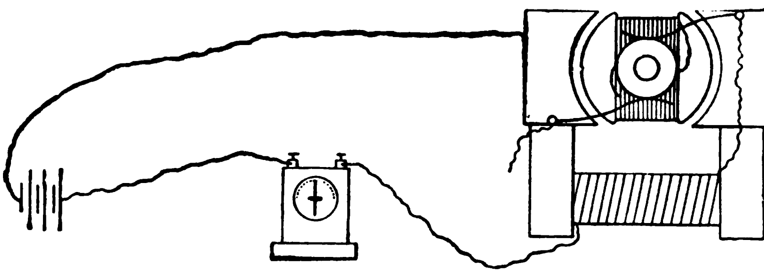


FIG. 6.

of the galvanometer to any bare iron portion of the field magnets. If there is any appreciable leakage, the deflection of the galvanometer needle will indicate the fact. This arrangement is illustrated at Fig. 6. In order to ascertain whether there is a leakage between the coils themselves (which is however, not very common), it will be necessary to calculate the resistance which the entire length of the

wire coiled on each limb of the field magnets should possess, by counting the number of layers and convolutions there are on each, and reckoning what resistance the observed length of wire of the gauge on the machine should have, and then measuring its resistance by means of a Wheatstone's bridge and set of resistance coils.* If it is found that the observed resistance is appreciably less than the calculated, it is a sign that there is leakage between coil and coil. If this be the case, the field magnet, which is defective, must be rewound. To detect leakage between the armature core and its coils, it will be necessary to proceed precisely as in the case of testing the field magnets; that is to say, having lifted the brushes from the commutator, connect one pole of battery to any of the sections of the commutator, and having connected the other pole of the battery with the galvanometer, take a wire from the

* Or if there are more than one field magnet coil, they may be connected separately to the two arms of a Wheatstone's bridge, and tested for resistance. If any very considerable difference be found between them, it may reasonably be inferred that the coils that indicate the lowest resistance are short circuited among themselves.

galvanometer to any bare iron portion of the armature, such as the spindle, or the nuts which hold the plates together. Any deflection will indicate leakage. To detect leakage between the individual coils themselves, the wires must be unscrewed from the commutator bars, and unfastened from each other, and each coil tested separately with a bridge and resistance coils; if any coil is found to be much less in resistance than its neighbours, leakage may be inferred. To detect leakage between the commutator bars, the armature wires having been previously disconnected, as just described, every commutator bar and its neighbour is in turn tested by means of battery and galvanometer. If any deflection takes place when any two bars are thus connected up, there is leakage between the two. In addition to the above accurate tests, a general rough test of the insulation of the field magnets and of the armature is obtained by leading a wire from one terminal of the dynamo (while the dynamo is running) to any bare iron portion of the field magnets; when, if any serious leakage between the coils and the iron at any part exists, bright sparks will be elicited on drawing

the wire along the surface of the iron. If, while a dynamo is running, it is found that one field magnet heats more than the other, it may be suspected that the cooler field magnet is short-circuited. To detect any leakage between brush-holders and rocker, it is advisable to remove the brushes from off the commutator, to connect each brush-holder in turn to the battery and galvanometer, and to try if there is any deflection on touching the rocker-bar. If there is any deflection, the insulation between the brush-holder and the rocker-bar must be seen to, and any defects made good by renewal of the insulator, be it ebonite, vulcanized fibre, boxwood, etc. If the wires or mains touch, this may be detected by the dynamo, if a series-wound one, running very stiffly and requiring much more power than usual to drive; if shunt-wound, it will *race* and go much faster than usual; if compound-wound, no difference will be observable in the driving, but the machine will probably spark at the brushes, and heat very much. If either of these defects are noticeable, and the machine is apparently not giving current on the outer circuit, the mains from the dynamo should be detached, and

the dynamo tried with a single pilot lamp directly on the terminals. If the lamp glows properly, it is a sign that the fault is in the mains or branches; and by going carefully over these the point of contact may be localized.

13. There is another cause for the failure of a dynamo to act, which, however, is most unlikely to occur in a new dynamo, and for that reason has been left till last; namely, a break either in the field magnet wires or else in the armature wires. The former is easily recognized from the fact that no current will pass, and consequently no deflection shown on the galvanometer, if one terminal of the battery be connected to the starting wire of the field magnet coils (which for this purpose must be disconnected from the brushes), the galvanometer being placed in connection with the other terminal of the battery, and contact effected between the ending wire of the field magnet coil. The detection of a break in the armature coils is rather more difficult; it can be effected in two modes: first, by uncoupling, one by one, the coils on the armature, and testing each one separately by means of battery and galvanometer;

or, second, by making a loop in the shape of the eyes used by dressmakers, or the Greek Ω, with the limbs sufficiently apart to bridge over two or three segments of the commutator. The dynamo being now set in motion, and this wire loop being held with gentle pressure against the commutator, as shown in Fig. 7, will probably begin to generate

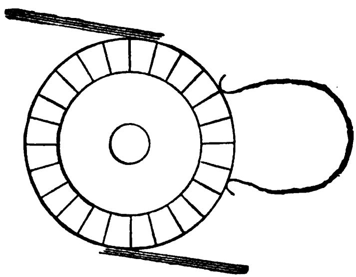


FIG. 7.

current, and a flash of light will be produced every time that the commutator bar, which is in connection with the coil that is broken, passes under the limbs of the loop. The same result will be apparent if there be a poor contact either between two adjoining coils of the armature or between the armature wires and any one of the commutator bars. Should this appearance present itself, the dynamo must be stopped, lest further injury be done; and

the position of the defective or broken coils can be localized by the burnt places on the commutator bars, caused by the flashes which take place at the points where the defects exist.

§ 14. In attempting to repair an armature, injuries to which may either be mechanical or through excessive heating, the engineer will do well, after having tested roughly where the defects may lie, as above described, to remove the armature bodily from the machine and place it carefully on a firm stand, having placed some clean cotton waste or tow underneath the armature, to prevent accidental abrasion. The mechanical injuries which may occur depend chiefly on small pieces of iron being sucked into the armature tunnel by the magnetism of the field magnets; and for this reason it is wise never to allow any small tools, such as spanners, files, nuts, screws, or nails, to be placed anywhere in the vicinity of the dynamo, as such pieces are sure to cut into the insulation or to destroy the binding wire which holds the armature coils in place. In like manner small pieces of waste or other extraneous matter may get carried into the armature tunnel, and cause injury either to the wire covering

itself, or to the binding wire. When the armature is out it should be carefully examined, and the damaged spots noted. These injuries will generally be superficial, rarely extending below the first, or at the most, the second layer. The binding wire or bands having been removed, the bared, twisted, or otherwise defective wires, should be carefully lifted by means of a bone paper-knife, and after having been covered at the injured portions with neat coils of silk twist, should be heavily varnished with some thick shellac varnish, and carefully replaced in their original position. Should any of the wires have been cut or broken, a scarf joint should be made (the insulation having been previously removed), and this soldered together with hard solder, the join bound round tightly with fine copper wire, again soldered, and lastly bound round with silk lute ribbon, and, finally, well shellaced. The coils are then replaced, and connected up as before to the commutator, having been previously pressed down so as not to protrude above the level of the armature circle, by gentle tapping with a mallet and smooth piece of wood. In the case of overheating, which, as we have seen, may be caused by overrunning the dynamo, by a

short circuit in the armature coils, or by short circuit between the commutator bars, the insulating covering of the wises frequently becomes charred or actually burned, and the smell will be enough to warn a careful engineer of what is taking place. The injury done in this case is more deep-seated than in the former, and the burning is generally more intense near the iron core of the armature. Consequently it will almost always be found necessary to rewind the armature entirely. In this case the directions given in the author's work, "Dynamo, How Made, and How Used," should be carefully followed; but unless the operator has had some practice in electrical work, it will be advisable to return the armature to the makers for repair. For this reason it is convenient to have at hand a spare armature in case of these eventualities, and most makers furnish spare armatures at a, comparatively speaking, small additional cost.

§ 15. Sometimes a dynamo, although not actually incapable of giving current, does not give the output expected from it. If none of the previous faults are found to exist, and especially if the pilot lamp, placed on the terminal of the dynamo for trial, shows that the

deficiency is not caused by a leakage in the outer circuit, or *ground*, as this defect is technically termed, it may be either that the dynamo itself is not capable of furnishing the stated output, or that through slip or other causes the speed is not sufficient. Careful examination of the belts, and testing the speed of the armature rotation by means of an ordinary speed counter, will soon certify whether this be the case; and the actual output of the dynamo can easily be measured by means of the *voltmeter* and the *ammeter* connected directly across the terminals of the dynamo.

§ **16.** Perhaps the most fruitful source of trouble with electric light installations is leakage from the mains to earth, or across to one another. The presence of this may be detected in the following simple manner :—Two lamps of the voltage usually employed on the main circuit are taken, choice being given to two which burn equally brightly. These two lamps are connected in series across the leads as shown at Fig. 8. Since their resistance is double that of any of the single lamps coupled in parallel across the leads, they will be found to glow very dimly. If, now,

a wire be taken from a point between the two lamps and connected to the ground by means of a metal plate shown at E, if there is any ground leakage, one of the lamps will be found to burn brighter than the other; and the leakage will be on that lead to which the most brightly-glowing lamp is connected.

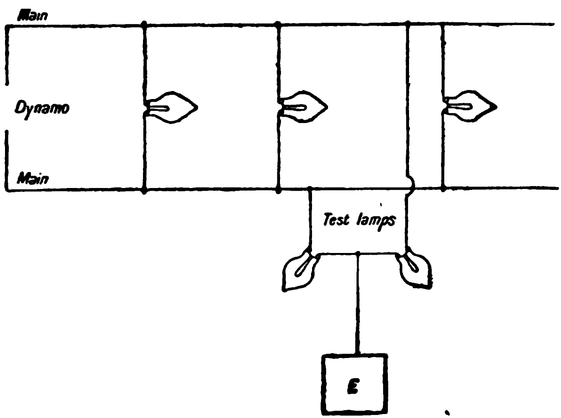


FIG. 8.

§ 17. To test for a leakage between lead and return, not a ground, switch off all the lamps, disconnect one lead from the dynamo, and place between this lead and the terminal of the dynamo, from which it has been disconnected, a galvanometer, coupled to both dynamo and lead by means of suitable wire, and at

such a distance from the dynamo as not to be influenced by its magnetism. Let the dynamo now be run; if there is no deflection there is no leakage.

§ 18. In conclusion, it may be remarked, that every care should be taken to keep the dynamo clean and *dry*. To this end, it should *not* be placed in the *engine-house*, if it can be avoided; and it should be covered, when not in use, with a clean *white* holland hood. Any dust that may settle on the armature or commutator may be blown away with a pair of bellows. On no account should iron tools be allowed to remain in the vicinity of the dynamo, for fear of their being gradually attracted, and finally sucked into the armature tunnel. No turning or other fitting should be permitted in the dynamo room, since metallic particles settling on the commutator or armature are sure to produce injurious results. For cleaning the dynamo, cotton or other waste is inadmissible, owing to the liability of fibre thereof being carried into the armature tunnel. Cloths having no fluff or loose fibres, should alone be used for this purpose.

DEFINITIONS.

Accumulator.—An arrangement by means of which a current of electricity is made to effect the decomposition of a fluid, the separated constituents of which, when the stress or strain set up by the passage of the current is removed, tend to reunite. If a connection is made between the two elements by means of a wire or other conductor, this re-composition takes place more or less rapidly, according to the resistance placed in the circuit, and is accompanied by a steady flow of electricity, until the re-composition has been fully effected. The accumulator consists virtually of two lead plates, immersed in dilute sulphuric acid (one part pure acid to four parts of water). Instead of a single pair of plates, a number of plates may be connected together on one side, to act as one single plate of large size, and a number of similar plates, also connected together, but separated from the first set, to act as another large plate. When a current of electricity

is passed through such an arrangement, by connecting one plate (or set of plates) to one terminal of any source of electricity, while the other plate (or set of plates) is connected to the other terminal, the water mixed with the sulphuric acid is split up into its constituents, namely, hydrogen and oxygen, the hydrogen being carried to the negative plate, and the oxygen going to the positive plate, with which it combines, forming on its surface a puce-coloured powder, known as peroxide of lead. If, now, the charging current be cut off, and the two plates connected by means of a wire, or any other conductor, a current of electricity is set up in the opposite direction from that of the original or "charging" current, while at the same time the oxygen and hydrogen leave their respective lead plates and reunite to form water. To effect this decomposition, and properly "charge" an accumulator, it is found that a pressure of at least two and a half volts is required.

Ammeter or Ampèrometer.—An instrument to indicate the amount of flow of current electricity. Three distinct types of ammeters are in general use. First, those in which the current of electricity is made to circulate round a coil of copper wire, in the vicinity of which is placed a delicately-poised

magnetic needle, which is moved farther from its usual position in proportion as the current is stronger. Secondly, those in which there is no magnetic needle, but in which the current is caused to flow round a spiral coil of copper wire (called a solenoid) near which is suspended a small piece of soft iron, that is sucked into the solenoid, to a greater or lesser extent, according as the current is larger or smaller. Thirdly, those in which a stretched wire, on being heated by the current, gets longer with the increase of current, and consequently of the heat. As the coils of all good ammeters should be constructed of metal of such a size as to present little or no appreciable resistance to the passage of the current, they may be placed directly in the main circuit of the dynamo, battery, etc. In this respect they differ from *Voltmeters* (which see).

Ammeters of the first class are useful for testing batteries, accumulators, etc., where there are no magnets or masses of iron to falsify their readings; they are *not* admissible for dynamo work, or in fact in any place where iron, magnets, etc., may act on their own magnets.

Ammeters of the second class, with its innumerable modifications, are largely used for dynamo and

other large installation work, and when carefully made, are very trustworthy.

Those of the third class have not as yet found very extensive application.

Ampère.—A measure of current electricity, bearing much the same relation to electricity as gallons do to the flow of water. As we cannot put electricity into a pot and measure it as we do water, we are obliged to measure the current by what it will do. It is found on trial, that if we cause ONE AMPÈRE of electricity to pass through a solution of sulphate of copper for one hour, we get a deposition of 18·35 grains of copper. If, instead of using a copper solution, we use a silver salt, say a solution of cyanide of silver, we deposit silver at the rate of sixty-two grains per hour for each AMPÈRE we cause to pass through the solution. Hence the earlier measurements of electricity were obtained by weighing the deposits effected in a given time by the current employed. As a guide to those in charge of electric light installations, it may be useful to remember that the ordinary sixteen candle-power Edison-Swan lamps marked 50 v., take about one ampère of current to light them properly; so that an installation of say one hundred such lamps placed in parallel, will need a current of 100

ampères, at a pressure of 50 v. The lamps of the same makers, marked 100 v. or 110 v. take about half an ampère. An ordinary *arc* lamp of about 1,000 candle-power takes a current of 8 to 10 ampères at a pressure between 45 and 50 volts, to give its proper light. It will be well to remember that in converting any form of mechanical energy (as that furnished by the steam-engine, water-power, etc.) into electricity, it requires a little over 1 horse-power to furnish 746 ampères at 1 volt pressure. If higher pressures are required, a corresponding increase must be made in the horse-power to be used. Thus, if 746 ampères at 2 volts pressure were required, two horse-power must be supplied. (See VOLT and WATT.) Since the ampères that can flow through any given circuit depend at once on the pressure, and upon the *resistance* placed in the circuit, it is evident that with any given dynamo, battery, or other source of electricity, the number of ampères flowing can be diminished by increasing the resistance, just in the same way that the flow of water from a water-butt would be reduced if a small tap presenting a considerable resistance to the passage of the water, were substituted for a large one having a larger bore, and consequently presenting less resistance.

On the other hand, the number of ampères flowing through a given circuit can (provided the pressure at the source, be it dynamo, battery, or other, be kept steady) be increased by simply diminishing the resistance. This explains why in certain forms of dynamo the armature coils, etc., may get so hot as to burn up the insulation from the excessive current they are called upon to carry, when, by inadvertence, the resistance in circuit is made too low, by placing too many lamps in parallel, or by short-circuiting the terminals of the dynamo in any manner.

Alternating Currents.—Currents which do not flow continuously in one direction, but which flow first in one direction and then in the opposite, rapidly reversing, are called alternating currents. Alternating currents are of no use for charging accumulators or for plating work. They may be, and are, used for certain kinds of motors; they are specially adapted for use with *transformers* (which see), and may be used with incandescence lamps, certain forms of arc lamps; while they are the only currents admissible for use with the Jablochkoff Candle.

Alternators or **Alternating Dynamos** are dynamos in which the opposite waves of electricity which are set up in the armature coils, when these approach

and recede from the pole pieces of the field magnet, are *not* rectified by the commutator, but allowed to traverse the circuit in the same directions as they are produced, viz., first in one sense, and then in the other. Many beautiful and powerful forms of alternators have been devised, such as the Kingdon and the Mordey. In most of the modern forms, a high rate of alternation in the opposite waves of current is obtained, varying from 80 to 125 reversals per second. When used in conjunction with *transformers*, the number of alternations (usually abbreviated ~~~~) should not exceed 100 per second.

Arc.—The bright light which is formed when the electric current bridges a gap between two conductors, is called an *arc*, which really means an arch, bridge, or bow. One peculiarity of the arc is, that when once formed, it sets up a counter electromotive force in the opposite direction to the current which produces it; and this electro-motive force has a pressure of about 39 volts; so that no steady arc can be produced unless the pressure of the current which is used to form it exceeds somewhat 39 volts. Another property of the arc is, that it can be blown aside by a strong current of air, or by approaching the poles of a magnet to it.

Arc Lamps.—An arrangement by means of which

light is produced between two pointed rods of gas carbon (graphite) separated at a small distance from each other (one-sixteenth to one-eighth of an inch), while a current is allowed to flow and form an *arc* (which see) across the gap. The electro-motive force required to produce the arc is about 45 to 50 volts; when once formed the current required will vary with the light required; it may be roughly stated that, up to 1,000 candle-power, it requires 1 ampère to produce each 100 candle-power; from 1,000 to 4,000, an increase of 100 candle-power is obtained for each half ampère of current additional; and from 4,000 to 15,000 candle-power, even less. Something, of course, depends on the particular make of the lamps; thus, lamps like the Equilibrium (Beaumont's), and the Midget, give the most economical results with comparatively small currents; while such lamps as the "Crompton," the "Brush," and the "Brockie Pell" are more economical when large currents are employed. All modern arc lamps are fitted with electro-magnetic devices whereby the same current that feeds the lamps regulates and keeps up the proper distance between the carbon pencils in proportion as these consume under the influence of the current.

Armature.—When any conducting body, such as a

wire or a rod of metal, is moved before the poles of a magnet (either permanent or temporary) in such a direction as to cut the lines of force of the said magnet, a current of electricity is set up in the wire or rod, which, by suitable means, can be led wherever desired. If the wire or rod be coiled around a mass of iron, the current set up is greater in consequence of the iron drawing to itself a greater number of the magnet's lines of force. Such an arrangement of coiled wires, either with or without an iron core, is called an *armature*, and as the armatures in most dynamos constitute the rotating portion, while the field magnets remain stationary, we may broadly define the armature of a dynamo as being "the wire-wound portion which rotates." But this definition does not hold good in all cases, since it is quite evident that the same results could be obtained if we caused the field magnets to move while the armature remained stationary; and, in fact, in the Mordey alternator, we have stationary a large, thin, compound armature, on each side of which rotate the claws of a peculiar spider-shaped electro-magnet.

Bursting of Lamps.—An incandescent lamp is said to "burst," when, owing to a too high voltage being employed, the current forced through it is too large

for the carbon filament to bear, when it breaks at the weakest point, and the light goes out. If lamps blacken inside quickly, it is a sure sign that the current used is excessive.

Circuit.—The entire line of conductors along which a current of electricity passes *from* and back *to* any generator of electricity, such as a dynamo, battery, or other. The circuit may consist of the *leads* or wires and cables, lamps, motors, etc., etc. This line of conductors is said to form an *open circuit* when there is any gap in the way; and then no current can flow; it is called a *closed circuit* when there is no interruption or hindrance to the passage of the current, so that the current can flow from the point of highest pressure (one terminal) to the point of lowest pressure (the other terminal of dynamo or battery.) A circuit is sometimes formed where it is not wanted; as, for instance, when by any means the covering of the wires on the dynamo or along the leads gets injured, so that the current leaks off without completing the circuit it was intended to traverse; these are known as *short circuits* (which see).

Conductors.—Bodies which allow electricity to pass through them freely. No substance is a *perfect* conductor; the metals, especially silver and copper,

are excellent conductors; while some bodies, such as dry air, paraffin, wax, shellac, india-rubber, sulphur, etc., present such an enormous resistance to the passage of electricity, that they have been called *non-conductors.* Most bodies when damp become pretty good conductors; so that the dynamo tender must be careful toavoid damp near his dynamo, or along his lines, for fear of a *short circuit.*

Connected in Parallel.—Lamps or other conductors are said to be connected in *parallel* when they are placed across the two main leads, like the rungs of a ladder.

Connected in Series.—Lamps or other conductors (including batteries) when strung together in one long line, like the separate links in a chain, are said to be in *series.*

Electro-motive Force.—Whatever tends to set up a current of electricity, or to produce a difference of electric pressure.

Incandescence, or **Incandescent Lamps.**—A lamp in which a filament or fine thread of some fairly conducting substance, not easily melted, is kept at a glowing white heat (incandescing) by the passage of a current of electricity. This filament, which in modern lamps is a hard form of carbon, obtained by charring threads of cotton, bamboo fibre, etc.,

between metal plates, does not *burn*, like the wick of a candle, as it is enclosed in a glass bulb, from which the air has been sucked out; it simply becomes *white hot*. Lamps as at present constructed take about $3\frac{1}{2}$ watts for every candle-power they give out. That is to say, a 5-candle-power lamp will take about $17\frac{1}{2}$ watts to keep it properly lighted. But the voltage and current may vary according to the resistance of the lamp. Thus the 5-candle-power lamp may be made to take $17\frac{1}{2}$ volts at 1 ampère $= 17\frac{1}{2}$ watts; or 35 volts, half an ampère $= 17\frac{1}{2}$ watts, and yet the light will be just the same. High voltage lamps of a given power take less current than low voltage ones of the same power.

Induction, or *Influence*, the peculiar effect which an electrified or magnetised body exerts on other bodies in its neighbourhood, by means of which their electrical or magnetic condition is disturbed, and this without any actual transfer or discharge of electricity or magnetism from the inducing body to that induced. In the case of electricity, the effect ceases with the removal of the electrified body, or with the removal of its charge; in the case of magnetism, if steel or hard iron be subjected to induction, the change set up is permanent.

Insulated.—Cut off from contact with anything which allows the passage of electricity; surrounded by non-conductors: thus, a wire supported at its two extremities on two inverted wine-glasses would be insulated, since glass is so bad a conductor that little or no electricity could escape. Dynamo wires are "insulated" by being wrapped with cotton, and varnished, etc. The leads are insulated by means of coverings of cotton, tape, ozokerite, india-rubber, etc. The higher the pressure (in volts) to which the conductors are subjected the better must be the insulation.

Insulating.—Cutting off the passage of the electricity.

Insulator.—Any substance which prevents, more or less effectually, the passage of electricity. The insulators generally used in dynamo work are, in the order of their efficiency, *paraffin*, *wax*, *ebonite*, *gutta percha*, *india-rubber*, *silk*, *glass*, *cotton*, etc.

Magnetic Field.—The whole space around the poles of a magnet, where the magnetic influence is felt. If a sheet of paper be placed over the poles of a magnet, and fine iron filings be sifted on to it, the filings will arrange themselves in certain curved lines across and around the poles, showing the "field" and the "lines of force."

Ohm.—The measure of *resistance* to the passage of

current. One foot of No. 36 B. W. G. iron wire has just about 1 ohm resistance. A column of mercury 40½ inches in height and one twenty fifth of an inch in square section has exactly 1 ohm resistance. It takes exactly 1 *volt* (which see) to force a current of 1 ampère, through a resistance of 1 ohm.

Polarity.—The condition or state of having a *north* pole at one extremity, and a *south* pole at the other.

Resistance.—Any opposition to the passage of the current. This is generally measured in ohms (which see).

Resistance Coils.—Coils of insulated German silver, or platinoid wires, having certain measured resistances, such as 1, 2, 50, 100, etc., ohms. Like pounds, ounces, etc., in ordinary weights, they can be used to measure other resistances. They are also used to place in circuit (which see) to cut down or reduce the current flowing.

Short Circuit.—A short passage, opened either accidentally or intentionally, along which the current can pass instead of going along the main circuit, as usual.

Transformer.—An instrument by means of which a large current at a high pressure can be converted into

a current of large volume but low pressure. Transformers are also constructed to effect the opposite result; viz., to convert a current of small pressure but large volume into one of high pressure but small volume. The total amount of energy, in *watts*, remains the same, less the loss entailed in conversion. Transformers consist essentially in bundles of soft iron wire, or masses of soft iron, wound with coils of two different sizes of copper wire, one coarse and one fine. If the current to be transformed passes into the fine wire coils, it sets up a current of lower pressure but larger volume in the coarse coils; if, on the contrary, it is made to traverse the coarse coils, the current set up in the fine wire coils will be one of higher pressure but lesser volume, and this in the ratio that the number of coils and the conducting power thereof bear to one another. To produce this effect, the current supplied to the primary coils (the ones through which the original is sent *must be alternating* currents (which see). There is no connection between the primary and secondary coils of a transformer; the primary acts on the secondary by "influence" or "induction" only.

Volt.—The measure of electrical pressure, very similar to pounds pressure, in speaking of a head of water.

An ordinary Daniell cell gives a trifle more than 1 volt pressure; a bichromate cell, an accumulator cell, a chromic acid cell, each give about 2 volts pressure; a Léclanché and a dry cell give 1½ volt pressure. Each *foot* of *active* wire on the armature of a dynamo gives about 1 volt pressure, if it moves in the field of a magnet at the rate of 1,250 feet a minute.

Voltmeter.—An instrument to indicate, in *volts*, the pressure at which the current is supplied. It bears the same relation to the dynamo or batteries as the Bourdon steam gauge does to a boiler; this latter indicates the pressure in pounds at which the steam stands, but does not indicate the amount produced: so the voltmeter indicates the pressure in volts of the electro-motive force, but does not give the amount of current passing. Owing to the great resistance of the voltmeter, it must not be placed *in series* with the mains, but *across* the terminals, *in parallel.*

Watt.—The measure of total electrical energy, both in pressure (volts) and current (ampères). Hence, 1 volt multiplied by 1 ampère is equal to 1 watt. One horse-power of mechanical energy is equal to 746 watts; and 746 watts of electrical energy, less the inevitable loss in conversion, are equal

to 1 horse-power. To know the power in watts given by any dynamo or battery, multiply the volts it gives by the ampères. For instance, a dynamo gives 30 ampères at 50 volts. How many watts? $30 \times 50 = 1{,}500$ watts. In trade language 1,000 watts are called 1 unit.

Wheatstone's Bridge.—An instrument to measure *resistances*. It consists virtually of two equal arms of conductors on either side of a central point, with a gap in each arm to admit of the insertion on the one side of a known resistance (one or more ohms), and on the other of the unknown resistance to be measured. Any difference in resistance is made evident by the deflection of a galvanometer connected up to both arms of the bridge. It is, in point of fact, a balance, or pair of scales, in which resistances can be measured.

INDEX.